Weed Technology 2007 21:76–79

Characterizing Weed Communities Among Various Rotations in Central South Dakota

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Producers in the Great Plains are exploring alternative crop rotations with the goal of reducing the use of fallow. In 1990, a study was established with no-till practices to compare eight rotations comprising various combinations of winter wheat (W), spring wheat (SW), corn (C), chickpea (CP), dry pea (Pea), soybean (SB), or fallow (F). After 12 yr, we characterized weed communities by recording seedling emergence in each rotation. Downy brome, cheat, redroot pigweed, and green foxtail were the most common weeds observed. Weed community density was highest for W–CP, being 13-fold greater than with Pea–W–C–SB. Downy brome and cheat were rarely observed in rotations where winter wheat was grown only once every 3 or 4 yr; in contrast, density of the brome species was 75-fold greater in W–CP. Warm-season weeds were also affected by rotation design; density of redroot pigweed and green foxtail was sixfold greater in W–C–CP compared with Pea–W–C–SB or W–F. One rotation design that was especially favorable for low weed density was arranging crops in a cycle of four, with two cool-season crops followed by two warm-season crops.

Nomenclature: Cheat, *Bromus secalinus* L. BROSE; downy brome, *Bromus tectorum* L. BROTE; green foxtail, *Setaria viridis* L. SETVI; redroot pigweed, *Amaranthus retroflexus* L. AMARE; chickpea, *Cicer arietinum* L.; corn, *Zea mays* L.; dry peas, *Pisum sativum* L.; soybean, *Glycine max* Merrill; wheat, *Triticum aestivum* L.

Key words: Rotation design.

No-till cropping practices have transformed crop production in the semiarid Great Plains (Peterson et al. 1993). With tilled systems, the prevalent crop rotation is winter wheat to fallow. However, preserving crop residues on the soil surface improves precipitation storage in soil such that more crops can be grown before fallow is needed again to replenish soil water (Peterson et al. 1996). With no-till systems, producers are growing a diversity of crops, such as corn, sunflower (*Helianthus annuus* L.), dry pea, soybean, and annual forages, along with winter wheat. In northeastern Colorado, no-till cropping systems increases land productivity twofold (Anderson et al. 1999) and net returns fourfold (AFPC 2005) compared with a winter wheat–fallow rotation.

Tillage management also affects weed community dynamics (Froud-Williams et al. 1981), but trends with no-till systems have been inconsistent. A rotation study in Alberta, Canada, showed that weed community density increased across time with no-till (Blackshaw et al. 1994), whereas a study in northeastern Colorado showed the opposite trend (Anderson 2005). Moyer et al. (1994) cited several published examples where weed species response to tillage management varied among studies.

One aspect of weed population dynamics affected by no-till is seed placement in soil; more weed seeds remain near the soil surface with no-till compared with tilled systems, thus altering seed survival (Froud-Williams 1988; Roberts 1981). To understand the interaction between tillage and seedbank dynamics, Mohler (1993) developed a model based on published literature. The model predicted that density of weed seeds in the seedbank would decline more rapidly with no-till across time, provided that new seeds were not added to the seedbank. The changes in cropping practices in the Great Plains because of no-till systems enable producers to design rotations with crops that have different life cycles, thus providing more opportunities to control weeds and reduce seed production (Anderson 2005; Leeson et al. 2000). Producers in this region may be able to enhance the effect of no-till on seedbank dynamics by how they sequence crops in rotation.

Moyer et al. (1994) noted that most studies comparing tillage management involved rotations with one or two crops and speculated that longer rotations with more crops in reduced-tilled systems may lower weed-community density. Derksen et al. (2002), analyzing contrasting responses of weed communities to tillage and crop rotation, also suggested that weed density may be lower with more diverse rotations in no-till systems.

In 1990, a long-term rotation study was established in central South Dakota that consisted of crops with different life cycles; eight rotations were established with no-till practices. In the twelfth cropping season, we characterized weed communities among rotations. Our goal was to gain insight for integrating rotation design with weed-management planning in no-till systems.

Materials and Methods

Study Design. The study was established in the fall of 1990 on a Promise–Opal clay soil (Udic Chromusterts) near Fort Pierre, SD. The soil contained 2 to 4% organic matter, with a pH range of 7.4 to 7.8. Annual precipitation averaged 430 mm across the past 30 yr, with 60% of precipitation occurring from April through July. During the data collection years, cropping season precipitation was 98% of normal in 2001 and 90% of normal in 2002.

Eight rotations were compared (Table 1), comprising various combinations of three cool-season crops, winter wheat

DOI: 10.1614/WT-06-020.1

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Table 1. Density of the weed community, brome species, and redroot pigweed as affected by rotations at Fort Pierre, SD. Brome species were cheat and downy brome.

Rotation[a]	Seedling emergence[b]		
	Weed community	Brome species	Redroot pigweed
	plants/m^2		
W–F	36 c	33 c	1 a
W–CP	94 d	75 d	13 b
W–C–F	11 ab	1 a	4 a
W–C–CP	40 c	1 a	12 b
W–C–Pea	11 ab	1 a	3 a
SW–C–SB	22 b	1 a	7 ab
Pea–W–C–SB	7 a	0 a	2 a
SW–W–C–SB	22 b	10 b	4 a

[a] Abbreviations: W, winter wheat; F, fallow; CP, chickpea; C, corn; Pea, dry pea; SW, spring wheat; and SB, soybean.

[b] Means within columns followed by an identical letter are not significantly different based on Fisher's Protected LSD (0.05).

(W), spring wheat (SW), dry pea (Pea), and three warm-season crops, chickpea (CP), corn (C), and soybean (SB). With some rotations, fallow (F), a 10- to 14-mo noncrop interval that preceded winter wheat, was also included. Plot size was 30 m by 75 m. The experimental design was a randomized complete block with four replications. All phases of each rotation were present in each year.

Crop Management. Cultural tactics for each crop were considered best-management practices for both crop management and weed suppression (Table 2). The diversity of crops led to a range of seeding and harvest dates, row spacings, and seeding rates. Cultivars commonly used by producers in the region were grown for each crop. Drills with disk openers were used to seed crops, resulting in minimal soil disturbance during planting.

Starter fertilizer of N and P at 8 kg N + 40 kg P/ha was banded with winter wheat, spring wheat, and corn seed, whereas the rest of N fertilizer was applied broadcast after seeding. Fertilizer level was based on target yield goals. Starter fertilizer of N and P at 3 kg N + 11 kg P was banded with the seed of dry pea, soybean, and chickpea; these crops also were inoculated with appropriate *Rhizobium* spp. in a granular formulation to facilitate N fixation.

For weed management, winter wheat and spring wheat were treated with bromoxynil + MCPA applied POST in early May at 0.4 + 0.4 kg ai/ha. With soybean, dry pea, and chickpea, metribuzin + imazethapyr was applied PRE at 200 + 15 g ai/ha within 7 d after planting.

For the first 10 yr with corn, atrazine + cyanazine + pendimethalin was applied PRE at 0.56 +1.12 + 1.12 kg ai/ha after planting. In 2000 and 2001, weeds in corn were controlled by acetochlor applied at 2 kg/ha PRE after planting and glyphosate applied at 0.6 kg ai/ha POST in a glyphosate-resistant hybrid. Glyphosate was applied between June 20 and June 25 in the 2 yr. The herbicide program also was changed with soybean in 2001; weeds were controlled by glyphosate applied at 0.6 kg ai/ha POST on July 7 in a glyphosate-resistant cultivar.

Glyphosate at 0.6 kg/ha controlled weeds present at planting in all crops. During fallow, weeds were controlled with glyphosate applied at 0.6 kg/ha as needed, ranging between three to five applications. Glyphosate application was timed to ensure that established weeds did not flower and produce seeds.

Weed Community Assessment. After 12 cropping seasons, we assessed weed flora and seedbank densities in all rotations. For seedbank analysis, 20 soil cores, 10 cm in diameter and 15 cm deep, were collected and composited in the fall of 2001. Sampling sites were 8 m apart and arranged in a W pattern across the plot. Procedures to quantify weed seedling densities in greenhouse trials followed Forcella (1992).

In December 2001, the entire study was planted to spring wheat. To assess weed flora in 2002, 10 0.1-m^2 quadrats were arranged in a W pattern, with two W patterns in each plot. Cool-season weed seedlings were counted and identified on May 1, when spring wheat was in the tillering stage. The field was then sprayed with bromoxynil + MCPA at 0.4 + 0.4 kg/ha. After spring wheat harvest, the entire site was sprayed with glyphosate to control any weeds present. Warm-season weed seedlings were counted in each plot in late July, after sufficient rainfall occurred to stimulate seedling emergence.

Fifteen species were observed, with downy brome, cheat, redroot pigweed, and green foxtail comprising more than 85% of the weed community (Table 3). Cheat and downy brome seedlings were not counted separately because of difficulty in distinguishing between seedlings of these species. Cropping history for the site before this study was winter wheat–fallow; prominent weeds were downy brome, cheat, kochia [*Kochia scoparia* (L.) Schrad.], and Russian thistle [*Salsola kali* (L.) Sennen & Pau].

Statistical Analysis. Seedbank and weed flora data were analyzed by ANOVA. Treatment effects were similar between weed flora and seedbank data; therefore, only weed flora data are presented. Weed flora densities are the sum of both assessment dates and were averaged across all crops within a rotation. Treatment means were separated with Fisher's Protected LSD at the 0.05 level of probability.

Table 2. Management practices for various crops grown in the rotation study at Fort Pierre, SD. Seeding and harvesting dates represent the time interval when operations occurred in 1990 to 2001.

Crop	Seeding date	Row spacing	Seeding rate	Harvest date
		cm	plants/ha	
Winter wheat	September 10 to 25	20	2.8 million	July 1 to 10
Spring wheat	December 1 to 15	20	2.8 million	July 10 to 20
Dry pea	March 20 to April 1	20	740, 000	July 15 to 25
Chickpea	May 1 to 10	40	370, 000	August 10 to 20
Corn	May 5 to 15	40	54, 400	October 10 to 25
Soybean	May 20 to June 1	40	430, 000	September 25 to October 5

Table 3. Weed species observed in the study and abundance of each species in the weed community, averaged across rotations.

Weed species			Percent of weed community
Common name	Scientific name	WSSA code	
Brome complex	*Bromus tectorum L.*	BROTE	47
	Bromus secalinus L.	BROSE	
Redroot pigweed	*Amaranthus retroflexus* L.	AMARE	23
Green foxtail	*Setaria viridis* (L.) Beauv.	SETVI	19
Kochia	*Kochia scoparia* (L.) Schrad.	KCHSC	2
Russian thistle	*Salsola iberica* Sennen & Pau	SASKR	1
Prickly lettuce	*Lactuca serriola* L.	LACSE	1
Annual sowthistle	*Sonchus oleraceus* L.	SONOL	1
Prostrate spurge	*Euphorbia humistrata* Engel. ex Gray	EPHHT	1
Lanceleaf sage	*Salvia reflexa* Hornem.	SALRE	< 1
Witchgrass	*Panicum capillare* L.	PANCA	< 1
Wild oat	*Avena fatua* L.	AVEFA	< 1
Buffalobur	*Solanum rostratum* Dun.	SOLCU	< 1
Canada thistle	*Cirsium arvense* (L.) Scop.	CIRAR	< 1
Common milkweed	*Asclepias syriaca* L.	ASCSY	< 1

Results and Discussion

Weed Community Response. The highest density of weeds, 94 plants/m^2, occurred in W–CP (Table 1). In contrast, only 7 plants/m^2 were recorded with Pea–W–C–SB, a 13-fold difference comparing these rotations. With W–F and W–CP, seedlings of cheat and downy brome comprised the majority of the weed community, whereas these species were seldom observed with rotations that included winter wheat only once every 3 or 4 yr. One exception occurred, however; 10 brome plants/m^2 were recorded in SW–W–C–SB. We attribute this trend to the early planting date of SW (dormant seeded in December [Table 2]), which allowed brome seedlings to emerge after spring wheat was seeded and produce seeds.

Density of warm-season weeds, primarily redroot pigweed and green foxtail, also reflected rotation design. The highest density of warm-season weeds was recorded in W–C–CP, a rotation with two warm-season crops in 3 yr (Figure 1). Warm-season weeds were also prominent in SW–C–SB and W–CP. In contrast, warm-season weeds were rare in rotations that included 2-yr intervals of cool-season crops or fallow, such as W–C–F or Pea–W–C–SB. Note the almost sevenfold difference in redroot pigweed densities between W–CP and Pea–W–C–SB (Table 1).

Including a 2-yr interval between winter wheat crops is a prevalent practice to manage downy brome in the central Great Plains, where warm-season crops, such as corn or proso millet (*Panicum miliaceum* L.) are added to the W–F rotation (Wicks and Smika 1990). Similarly, a 2-yr interval of winter wheat and fallow in winter wheat–proso millet–fallow almost eliminated warm-season weeds compared with continuous proso millet or winter wheat–corn–proso millet (Anderson 2003). The 2-yr interval provides opportunities for producers to control weeds with different life cycles and prevent seed production, thus enhancing the rapid decline of weed seed density in soil with no-till. Consequently, fewer weed seedlings emerge in following crops. Arranging crops with 2-yr seasonal intervals was also effective in our study, as shown by the low weed density in W–C–F (Table 1). Weed control during fallow eliminates seed production of both cool-season and warm-season weeds. However, the 2-yr interval approach also was effective with continuous cropping, as shown with Pea–W–C–SB.

Associations Among Specific Weeds and Crops. We also noted some crop–weed associations that may suggest future problems. Annual sowthistle (*Sonchus oleraceus* L.) established readily in chickpea, leading to high density of this species in the subsequent winter wheat (W–CP and W–C–CP). Also, prickly lettuce (*Lactuca serriola* L.) was common in dry pea, especially with W–C–Pea. The perennial weeds, Canada thistle [*Cirsium arvense* (L.) Scop.] and common milkweed (*Asclepias syriaca* L.), were observed in SW–C–SB, but not with other rotations.

Insight for Designing Semiarid Rotations. In a review of weed management, Mortensen et al. (2000) encouraged scientists and producers to broaden their perspective in considering weed-control tactics. They suggested that design of cropping systems be considered in weed management. Our results support this suggestion, as weed community density varied 13-fold among rotations (Table 1). The impact of rotation design was amply demonstrated with the *Bromus*

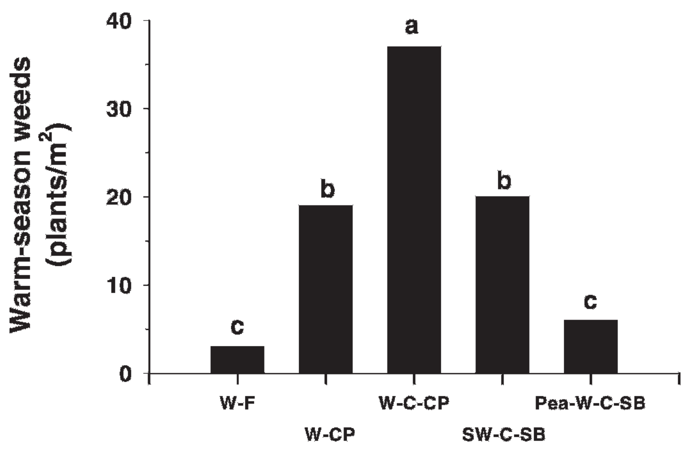

Figure 1. Impact of rotation on density of warm-season species. Bars with identical letters are not significantly different based on Fisher's Protected LSD (0.05). Abbreviations: W, winter wheat; F, fallow; CP, chickpea; C, corn; Pea, dry pea; and SB, soybean.

species; with no herbicides used to control these weeds, density varied 75-fold among rotations. Even when weed species were controlled by herbicides, rotation design still affected weed density. Weed control tactics in C and SB were identical with SW–C–SB and Pea–W–C–SB, yet density of warm-season weeds was fourfold greater in SW–C–SB (Figure 1). The 2-yr interval of cool-season crops with Pea–W–C–SB suppressed population growth of these weeds in addition to herbicide management.

The herbicide program used by producers will affect the interaction between rotation design and weed communities; impact of rotations will be less if highly effective herbicides are used because less weeds will survive control tactics and produce seeds. Conversely, the rotational effect on weed density likely will be greater with herbicide programs of lower efficacy because the benefit of crops with different life cycles in disrupting population growth of weeds will be accentuated compared with rotations of less crop diversity.

Producers will gain ancillary benefits with low weed-community density. Both foliar- and soil-applied herbicides are more effective at lower weed density (Dieleman et al. 1999; Winkle et al. 1981). Also, some crops grown in this region, such as proso millet and foxtail millet (*Setaria italica* (L.) Beauv.), do not have many herbicide options to control weeds. Fields with low weed densities will reduce the impact of weed infestations in these crops. A third benefit is that input costs for weed management can be reduced. Producers in northeastern Colorado control weeds with 50% less cost in rotations such as winter wheat–corn–proso millet–fallow compared with winter wheat–fallow or winter wheat–proso millet (AFPC 2005; Anderson 2005). Because of low weed density with the 4-yr rotation, both winter wheat and proso millet are grown without needing herbicides for weed control.

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Received February 2, 2006, and approved April 28, 2006.